Upgrading the CEBAF Accelerator to 12 GeV

Leigh Harwood (for the 12 GeV Project team)

TJNAF, 12000 Jefferson Ave, Newport News, VA 23606 USA

Abstract. Jefferson Lab is preparing to upgrade its 6 GeV Continuous Electron Beam Accelerator Facility (CEBAF) to 12 GeV. The doubled energy will significantly extend research reach of the three existing experimental Halls A, B and C, and the upgrade will add scientific capability, with a newly constructed hall, Hall D. Areas of special initial interest are reactions at high $x_{Bjorken}$, GPD's and exotic hybrid mesons. The present linacs will have their acceleration roughly doubled through the addition of 10 new cryomodules which will perform at ~5 times the original specification for CEBAF. The cryogenics plant will be roughly doubled and new rf systems will be installed for the new cryomodules. The beam transport system will strongly leverage existing hardware but must be enhanced with new power supplies, one new recirculation arc, and a beamline to the new Hall D. A brief description of the scope for the various accelerator subsystems will be given as well as the status of the project as a whole.

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OVERVIEW

Since its inception, the Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Lab has been a world-leading institution in extending the understanding of the quark-structure of matter and non-perturbative QCD. Extending CEBAF's beam energy to 12 GeV will extend those investigations to valence quark behavior, nuclear tomography with generalized parton distributions, and potentially unraveling the mystery of quark confinement through hybrid meson spectroscopy. The proposed overall research program received a strong endorsement by a review committee chartered by the Department of Energy (DOE) in April, 2005 [1].

The most cost effective route to upgrading from 6 GeV to 12 GeV plus house all the desired experimental systems is to increase each of the two linacs' voltages from 0.6 MV to 1.1 MV, thereby providing 11 GV of acceleration in 5 passes. Then a tenth recirculation arc is added so that the beam will transit one linac an additional time before being delivered to a new experimental hall which will house the hybrid meson experiment. The layout of the upgrade is given in Figure 1.

ACCELERATION

Note: The details of the acceleration systems (cryomodules, rf, and cryogenics) are described in detail in ref. [2]. The following is a summary of that information. It should be remembered that the existing acceleration systems will be used without modification.

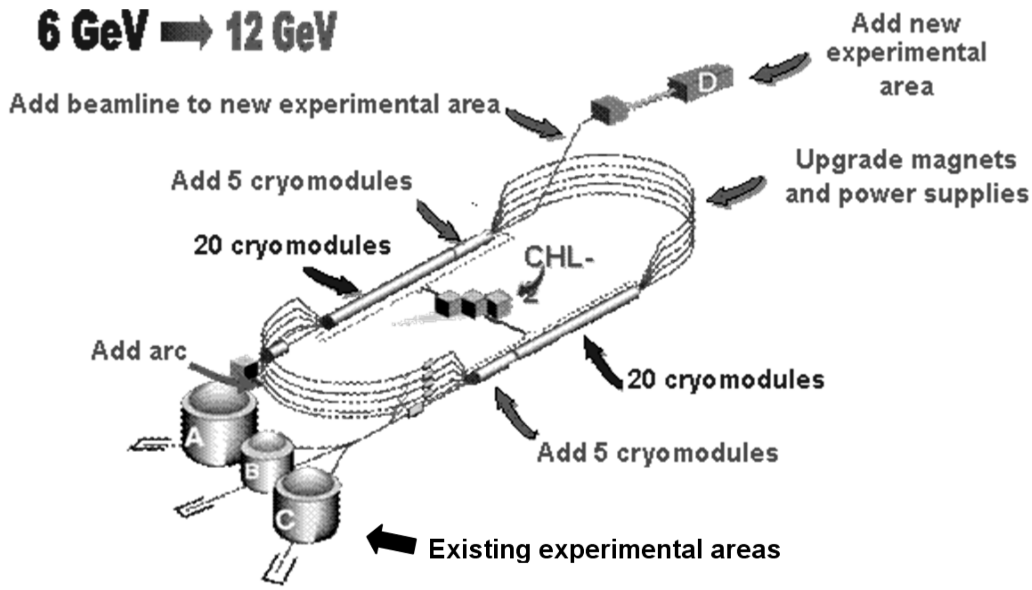

Figure 1 Conceptual illustration of upgrading CEBAF to 12 GeV

Cryomodules

The additional 0.5 GV/linac increase will be achieved by adding 5 new cryomodules (total of 10 needed for both linacs) each providing 100 MV. Each cryomodule will have eight 7-cell cavities. While only 17.5 MV/m is required for the cryomodule to reach 100 MV, the specification was set at 19.2 MV/m to overcome the potential that some cavities might be off-line. A limit of 29 W of 2K dynamic heat load (Q0 =8x109) was set by the requirement to fit within the projected cryogenics plant's capacity (see below). Prototype cavities have performed within the 29 W limit at 21 MV/m. A developmental cryomodule (designated "Renascence") was constructed based on the design planned for the 12 GeV Upgrade. Testing during 2005 showed that some features of the cavity design needed improvement, i.e. in the endgroups. Improvement of the endgroup thermal performance is part of the 12 GeV Upgrade R&D plan.

Cryogenics

The present 2K helium plant is now operating at its full capacity. In anticipation of the Upgrade project, JLab acquired from LLNL the former MFTF-B helium plant, which has a capacity of >10 kW at 4K. We also have a redundant ("hot spare") 2K coldbox which will be combined with the reconditioned MFTF-B plant and an 80K exchanger to construct a 2K plant with maximum capacity of ~5 kW at 2K. After allowance for system control headroom, there would be ~300W available for each of the new cryomodules, 250W of which would be available for dynamic load.

Radio-frequency power and control

Each cavity will be energized by its own power source. Up to 450 μA of beam could be transiting a cavity and sufficient power must be provided to operate exceptionally good cavities at up to 21.2 MV/m. A margin must be allocated for the cavities being off-resonance; presently we assume □ 25 Hz. Folding these factors plus reasonable engineering margin into the calculation, 13 kW power sources are needed. As of the date of this writing, a commercial firm has demonstrated 16 kW output from a klystron at CEBAF frequency. An improved low-level rf control module is required. Development work on a new digital system is presently underway in collaboration with Cornell, and DESY. A prototype system was tested this year (2005) and met the performance requirements of 0.01% amplitude control and 0.2° phase control.

BEAM TRANSPORT

The existing beam transport system consists of ~400 dipoles (B*L≥0.2T-m) and ~700 quads. Calculations of the emittance growth from synchrotron radiation of the electrons in dispersive sections of the beam transport found that the present 1 nm-rad emittance at 6 GeV will increase to ~10 nm-rad at 12 GeV. This emittance is consistent with the needs of the planned research program; thus, the existing optics and associated magnet configuration can be retained.

Fields in the existing beam transport system must be roughly doubled in order to deliver 12 GeV beams. Strategies have been developed which meet that goal but do not require replacing many magnets. To forestall saturation in the 250 of the 340 major dipoles located in the recirculation arcs, we will add iron which will change them from "C" designs to "H" designs; the remaining 90 will be replaced. Only 10% of the ~700 quadrupoles must be replaced with new magnets; another 10% will get stronger power supplies (testing has shown that they can be driven to 130% of design field without significant change in field quality). Fifteen of the 36 large (<750kW) dipole power supplies will be replaced.

A new recirculation arc will be added to bring the 5-pass beam back to the North Linac for continued acceleration. A beamline from the end of the North Linac to Hall D will be added. The optics and magnet designs for each will be slight variations on existing designs.

PROJECT STATUS

DOE approved Critical Decision 0 (Mission Need) in March, 2004. DOE conducted a "Lehman" review of the project in July, 2005; the review committee's report stated, "The Project is ready to move to the next phase." Approval of Critical Decision 1 (Approve Alternative Selection and Cost Range) is anticipated for early 2006 with a cost range of $225M-300M. Construction is scheduled to begin in 2008 and will require approximately one-year suspension in accelerator operations. Research at 12 GeV is planned to begin 2012.

ACKNOWLEDGEMENTS

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